WONDERS OF FOSSILS

WILLIAM H. MATTHEWS III

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Wonders of
FOSSILS

William H. Matthews III

Illustrated with photographs and drawings

Fossils are keys to the past—clues to life millions of years ago and the great changes our earth has undergone. Without them we would not know about dinosaurs or woolly mammoths, prehistoric plants or the first bird.

Fossils come in many forms—as bones, footprints, petrified wood, preserved in amber, tar, ice, and coal, as casts and molds, gastroliths and coprolites. They may be entire insects or leaves, or only parts of an organism.

Here you can find out about all the different kinds of fossils—how they came to be preserved, the significance of various fossils, how they are classified, major "finds" by both professionals and amateurs. There are helpful hints on fossil collecting, an exciting yet inexpensive hobby, and advice on displaying your collection.

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Courtesy of Field Museum of Natural History

By studying fossils such as these of horses, we can trace the development of animals through geologic history

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Wonders of FOSSILS

William H. Matthews III

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To Dominick and Margaret Anzalone

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Courtesy of Field Museum of Natural History

Deposits of dinosaur bones are usually found as the result of careful planning and scientific prospecting

1

Desert Boneyard

It was August 17, 1909. On a hillside in Utah two men carefully studied the sun-baked rocks. The desert is hot in August, but these men did not mind the heat. They were very excited, for they had just "struck it rich."

Had these desert prospectors uncovered a valuable vein of gold or silver? No, these men had uncovered a scientific treasure —there in the sandstone lay the tail bones of a huge dinosaur!

The excitement of the scientists was quite understandable, for they had spent many weeks searching for their prize. Even more time had gone into careful preparation for their dinosaur hunt. Leaving nothing to chance and armed with maps and collecting equipment, they had carefully examined the ground for clues. The clues were not always easy to find. Perhaps they would see only a tiny fragment of bone. Or possibly a suspicious bump on the surface, a bump that experienced eyes recognized as a buried bone.

But though the long, hot search was ended and the prize had been found, the scientists' work had really just begun. Slowly and skillfully they chipped away the rock as one by one they uncovered more bones. Finally, the dinosaur skeleton was exposed—only the skull was missing.

Good news travels fast in scientific circles, and it was not long before other scientists came to dig in the Utah sandstone. Soon many more dinosaur remains were found. These skeletons were of all shapes and sizes. One was as long as two railroad cars; another was no longer than a dog. Some of these unusual crea-

Courtesy, Department of Geology, Lamar State College of Technology

In his search for the past, the paleontologist studies fossilized remains of plants and animals that once inhabited the earth

tures had moved about on four legs, but others had walked only on their hind legs. One dinosaur was quite different from all the others, for it had great bony plates along its back. This peculiar plate-backed dinosaur also had four large spikes near the end of its tail and was nearly 20 feet long.

Why, you may ask, do so many dinosaur bones occur in one place? Many millions of years ago, Utah was quite different from what it is today. In those days, this section of the United States was very swampy, and the climate here was moist and warm. Dinosaurs and other reptiles liked the warm swamps and lived there in great numbers.

During this chapter of earth history a great river crossed the Utah swamps, and in the center of the river there was a large

sand bar. At times, dinosaurs tried to cross the river. Some of them became bogged down in the sand and, because they could not free themselves, many of them died there.

Upstream other dinosaurs also tried to cross the deep water. But as they entered the stream the swift current swept them away and many of them were drowned. Their bodies floated down the river and washed up on the sand bar. Slowly, it became a dinosaur graveyard. Today the river is no longer there and the sand bar has turned to sandstone, but the bones we see are the fossilized skeletons of the dinosaurs that lost their lives in that ancient river.

You can visit this desert boneyard called Dinosaur National Monument. There in the Utah sands you can see bones embedded in the rock—just as they were originally found. You can also see the scientists at work uncovering still more dinosaur bones.

Of course, dinosaurs do not live in Utah today. In fact, no one has ever seen a living dinosaur, for although they once lived all over the world, these great creatures have been extinct for about 65 million years. The Utah dinosaur bones are *fossils*. Fossils are evidence of prehistoric plants or animals that have been preserved in the rocks of the earth's crust. But dinosaurs are not the only kinds of fossils; evidence of many other organisms has also been found preserved in the rocks. By studying the fossilized remains of clams, snails, fish, birds, trees, and other organisms that lived million of years ago, it is possible to learn much about prehistoric life on our planet.

Rocks which contain some indication of prehistoric life are like the pages of a great history book, and the fossils are like pictures in stone. They are "pictures" of life long ago. *Geologists*, scientists who study the earth, read these rocky "pages" to learn more about ancient life and the great changes that our earth has undergone.

2

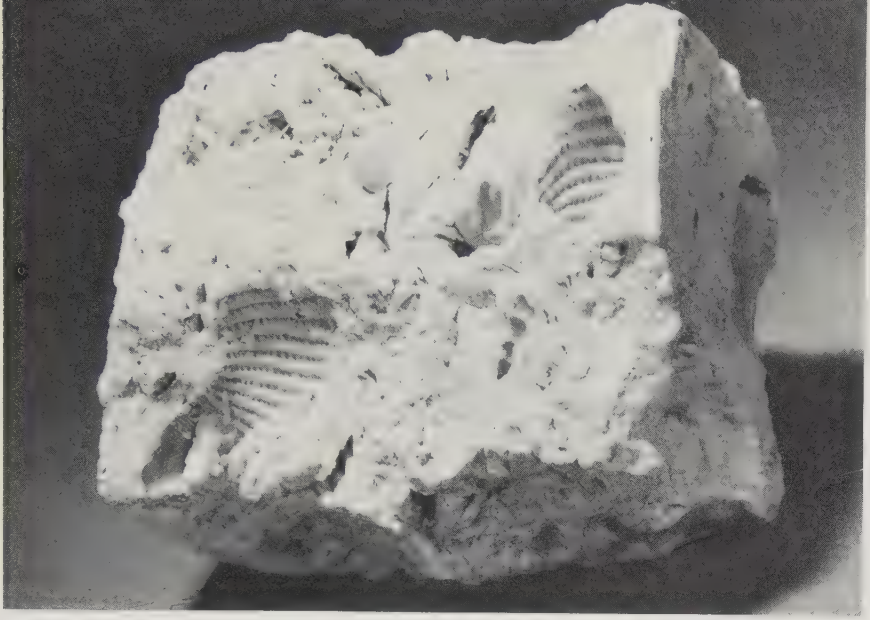
From Bone to Stone

WHAT PROCESSES might have changed the bones of a dinosaur or the shell of a clam into fossils? And how did the fossils get into the rocks and why did they not decay and disappear during the long time that they were buried? To answer these questions we must turn back the clock many millions of years to a time when the entire earth was quite different from what it is today.

During that part of geologic history our earth did not look as it does now. In those days, a great sea covered much of the land and along the shore many streams emptied into this ocean. As they flowed to the sea, each stream carried bits of rock and soil called *sediment*. Some of the sediment settled to the bottom of the stream, forming layers of mud and sand. Other rock fragments were carried to the sea and deposited on the ocean floor.

Year after year rock particles continued to pile up, until in some places they were more than a mile thick. The great weight of this sediment caused pressure on the bottom layers of mud and sand, and the rock fragments in these lower layers eventually became tightly pressed together. At about the same time, chemicals in the water cemented the rock particles tightly together. Finally—after perhaps hundreds of thousands of years—the cementing and pressure turned the sediment into solid rock. Rocks formed in this way are called *sedimentary rocks*. Sandstone, limestone, and clay are examples of sedimentary rock.

There were many plants and animals living in the ancient sea and still others lived along the shore. When these plants and



Courtesy of Ward's Natural Science Establishment

This piece of fossiliferous limestone was formed from sediment that contained the remains of ancient sea creatures

animals died, some of their bodies became mixed with the sand and mud. Most of their remains were eaten by other animals or decayed in the wet sediment, but if the animals had hard parts such as shell, teeth, or bones, these might have been preserved as fossils.

How can the bodies of plants and animals be changed into fossils that can resist destruction over such vast periods of time? Although this can happen in several different ways, it is more likely to occur if the plant or animal had hard body parts. Fossilization is also more likely to take place if the remains were buried soon after death.

But the exact way in which the fossil will be formed depends in part upon what its skeleton was composed of. Some remains were replaced by minerals and others have been preserved in coal or tar. A few have even been frozen.

Perhaps you have seen petrified wood, for it is a rather common type of fossil. But do you know how the wood was turned to stone? Let us suppose that a log sank to the bottom of an ancient

This stone log is a common type of fossil in Petrified Forest National Park in Arizona

R. B. Marshall, courtesy of United States Geological Survey

river. As time passed it became buried by thick layers of sediment. Next, the log became filled with water that seeped down through the rocks. The wood of the log was slowly dissolved and minerals deposited by the water took the place of the wood. Finally—after millions of years—the log was changed into solid rock.

Fossils formed in this way are said to be *petrified*. You can see large numbers of petrified trees in the famous Petrified Forest National Park in Arizona. There the great stone logs lie scattered about the surface as if chopped down by some prehistoric woodsman.

Another forest of petrified trees can be seen in Yellowstone National Park. These stone trees are especially unique, for they are not lying upon the ground. Instead, many of their trunks are still upright, standing where they grew millions of years ago before they were buried by falling ashes thrown out by nearby erupting volcanoes. Much later in geologic history water seeped through the ashes, dissolving minerals from them. These minerals were then deposited in the trees, bringing about their petrification.

The bones of animals that have died may also be replaced by minerals. Perhaps an animal was buried in quicksand. As time passed, water in the sand slowly dissolved the bone and replaced it with minerals. In other bones, mineral matter was deposited in the tiny holes in the bone, thus making it very hard and quite heavy. In short, the bones had become fossilized.

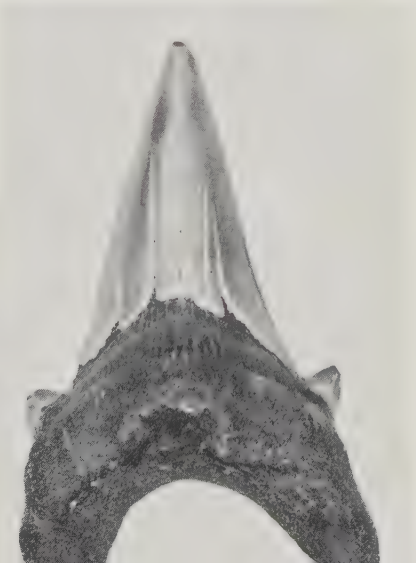
The shells of ancient clams, snails, and other sea creatures have also been replaced by certain kinds of minerals. Indeed, many of these shells are so well preserved that they look much as they did when the animals within them were living millions of years ago.

Fossils have been preserved by a number of different minerals. One of the most common of these is *quartz*. A very hard mineral, quartz is common in sandstone. It is found in many fossilized bones, shells, and plants.

Calcite is another mineral that is commonly found in fossils. Calcite is softer than quartz and is the most abundant mineral in limestone. Most limestone is composed of hardened sediment

This fossil snail shell (left) is composed of calcite, a mineral that commonly replaces original shells. The shark's tooth (right) is millions of years old, yet in a perfect state of preservation.

Courtesy of Malick's Fossils



that accumulated on the body of ancient seas. Thus, many prehistoric seashells have been fossilized by calcite derived from the limy sediment that surrounded them.

Sometimes animal remains are preserved by tar. The La Brea tar pits in Hancock Park in Los Angeles, California, are especially famous for fossils of this sort. These pools of tar, which formed on the earth's surface many thousands of years ago, have yielded hundreds of thousands of practically unchanged bones. The tar acted as an antiseptic which killed the bacteria that would have otherwise caused the decay of the bones. The skeletons of woolly mammoths, saber-toothed cats, giant ground sloths, and other now-extinct Ice Age animals are particularly abundant.

But the most remarkable--and rarest—fossils are the remains of animals that have been preserved in ice or frozen soil. The most famous of these fossils are the great shaggy-coated creatures called woolly mammoths. The frozen tundra of Siberia and Alaska has yielded the bodies of large numbers of these extinct elephant-like beasts. Some of these huge carcasses have been so well preserved that their flesh has been eaten by dogs and their tusks sold by ivory traders. Even the hair, blood, and skin have been preserved, yet these mammoths have been dead for some 25,000 years! The icy soil has kept their soft parts from decaying. The bones of extinct bison and other Ice Age creatures have also been found preserved in this manner.

Under rare circumstances even such fragile organisms as insects and spiders may become fossilized. Many of these animals have been preserved in *amber*—a type of fossil resin. This kind of preservation took place when prehistoric insects became trapped in the sticky gum that oozed out of certain cone-bearing trees such as the pine or fir. As time passed, the resin hardened, leaving the insect undamaged and entombed in the amber. Some specimens are so well preserved that their muscle tissue

Courtesy of Los Angeles County Museum

The bones of thousands of prehistoric animals have been found preserved in the La Brea tar pits in Los Angeles, California

The carcass of this fossil bison, which lived more than 30,000 years ago, was found in frozen soil in Alaska. Such perfectly preserved specimens are among the rarest of fossils.

Courtesy of Dr. Troy L. Péwé

This caddis fly is preserved in amber (fossil resin)

Courtesy of Smithsonian Institution

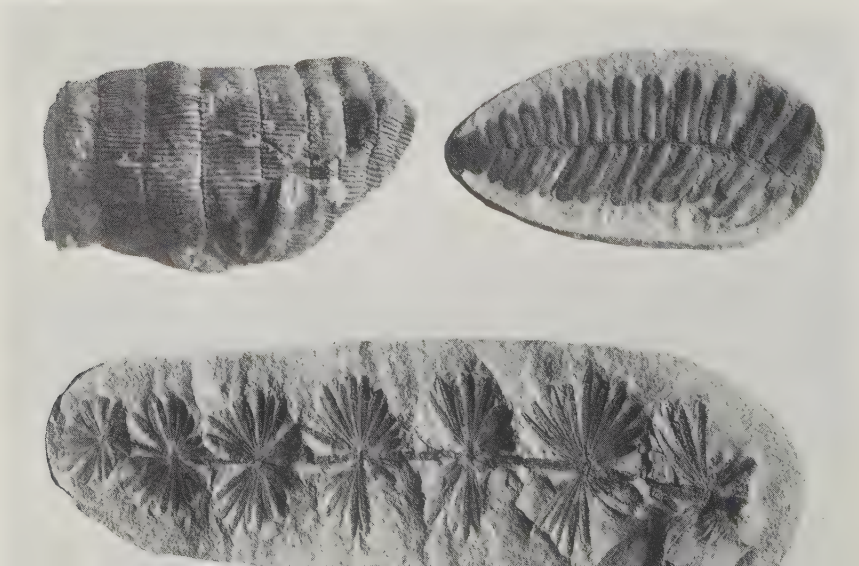
and internal organs may be studied under the microscope. Even such delicate material as fossil spider webs have been preserved in this way.

Plant fossils are commonly found preserved in coal. These fossils often represent plants that lived in swamps more than 200 million years ago. When the plants died they fell into the swamp and there they were slowly changed into partly fossilized plant material called *peat*.

With the passing of time, the peat was covered with mud and sand. The weight of this sediment produced great pressure and

"Coal plants" such as these are commonly found preserved in coal deposits formed during Mississippian and Pennsylvanian times

Courtesy of Field Museum of Natural History



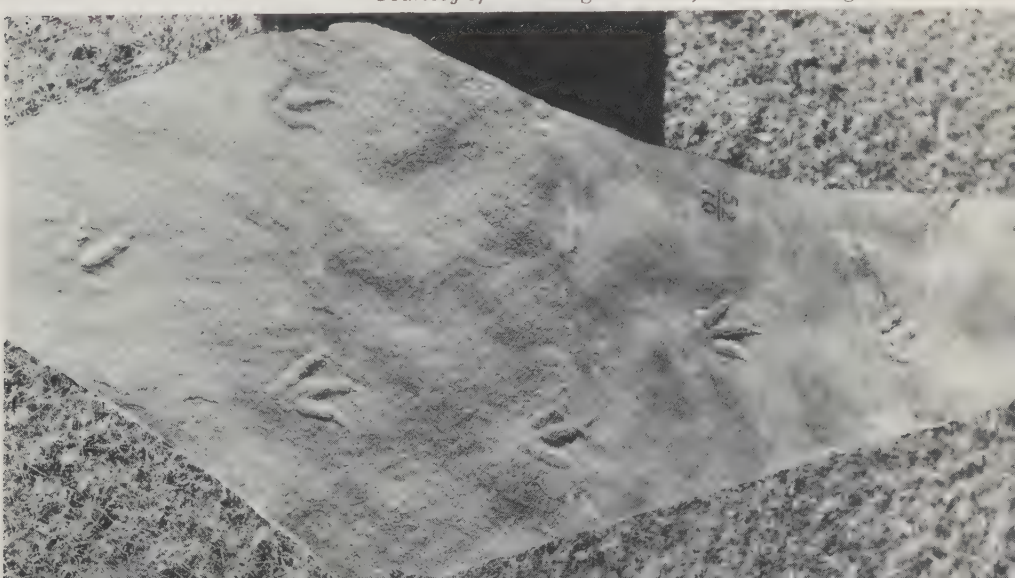
heat and caused gases and moisture to be squeezed out of the closely packed peat. Finally, after millions of years, the peat was turned into coal. However, one can still see evidence of some of the ancient plants from which the coal was formed. This type of fossilization is called *carbonization*, and the fossils thus produced resemble "carbon copies" of the original plant.

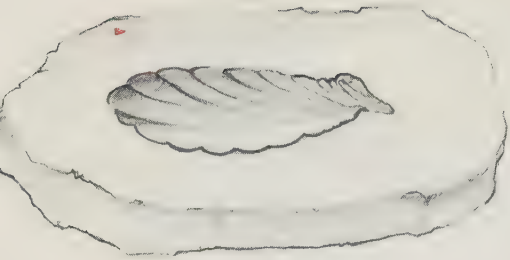
But fossil bones, shells, and trees are not the only kinds of fossils. Some animals have left only a trace of their existence. Huge footprints have been found in certain rocks of the earth's crust. These tracks were made as animals—perhaps dinosaurs—walked through soft mud or sand at some time in the geologic past. Even though the animals' bones may not have been found with the tracks, these stony imprints are proof that the animals once lived in the area in which they are found. When studied by *paleontologists*—geologists who specialize in the study of fossils—these footprints may provide evidence of the weight, length, and kind of dinosaur that left the tracks.

Some fossils show only the shape of the original animal. *Molds*

This slab of sandstone of Triassic age contains several dinosaur footprints. Made by a two-legged dinosaur, the tracks on the smooth part were formed under water. The rougher area shows the effect of raindrops, or possibly freezing.

Courtesy of Dr. George W. Bain, Amherst College





MOLD

CAST

Molds and cast are common fossils. They provide information about both the interior and exterior of an animal shell.

and *casts* are good examples of this kind of fossilization. To see how these are formed, let us consider a seashell buried in ocean sediment. After the sediment has hardened under pressure, ground water may slowly dissolve the shell, leaving a cavity in its place. This cavity becomes a *mold* that shows the nature of the exterior of the shell. If the mold should later become filled with more sediment or mineral matter deposited by ground water, a *cast* of the fossil is formed. These *natural casts* show how the body originally appeared. Many fossils are preserved only as molds and casts.

Especially interesting are the relatively rare fossils called *gastroliths*. Known also as "gizzard stones," these highly polished, well rounded stones are occasionally found with the remains of certain extinct reptiles. Because they are similar to the small stones found in the gizzards of birds today, it is believed that gastroliths were present in ancient reptiles and were used to grind up their stomach contents.

Equally unusual are *coprolites*, a word which means "dung

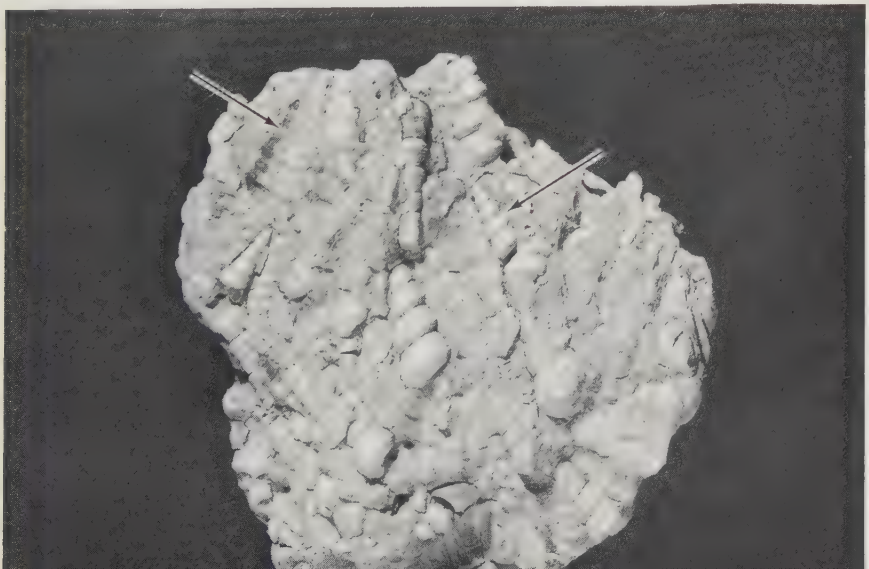
stone." Such fossilized dung or body waste can provide valuable information as to the food habits or body structure of the animal that left them.

When working with *trace fossils* such as tracks, molds, coprolites, and gastroliths, the paleontologist must turn detective. Luckily, he can use this "circumstantial evidence" to reconstruct the characteristics and habits of life forms that vanished from the earth hundreds of millions of years ago. And in so doing, he has learned much about the various organisms that have populated the earth during the past two billion years.

Did all of the prehistoric plants and animals leave a record of their existence? Unfortunately, the answer is no. It has been estimated that only one out of every million living organisms had a chance of becoming fossilized. This is because natural processes usually destroyed their bodies and because they were not quickly buried in the proper type of sediment to preserve them. And so, although large numbers of fossils have been discovered, many others will never be found. Many fossils have been destroyed by great earth movements; countless others have been

These Eocene sea snails have been preserved as *molds* (upper left arrow) and *casts* (right arrow)

Courtesy of Smithsonian Institution



The coprolite shown here represents the fossilized body waste of a prehistoric reptile
Courtesy of Malick's Fossils

destroyed by wind, rain, and running water. Consequently, it is entirely possible that some forms of life may never be known to us because they never had the chance to become preserved.

Most of the animal remains that became fossilized represent parts of *marine* animals—creatures that lived in the sea. This is not surprising, for decay is slower in water than on the land. Then, too, the sea floor is usually covered with soft sediment which may quickly cover the animal before it can be destroyed.

On the other hand, *terrestrial* (land-dwelling) forms are less commonly preserved because of more rapid decay. In general, there is also a lack of suitable places of burial on the land. Of course, there are exceptions to this, for we have already learned that plant fossils may be found associated with swamp deposits that formed on land. Moreover, many dinosaurs and other terrestrial animals are preserved in stream sediment that was deposited on land.

But despite the countless billions of plants and animals that left no record, many organisms *did* become fossilized. When found and studied by the paleontologist, their remains are important clues in reconstructing the development of life on earth.

3

In Search of the Past

Of what use are fossils? How could the shell of a microscopic animal that lived 400 million years ago be of any possible value in this day of "space age" science? And what can we hope to learn from the study of a 100 million-year-old footprint? These are but a few of the questions the paleontologist is asked about the uses of fossils.

There is considerable evidence to suggest that man has wondered about fossils much longer than most of us realize. Fossil shells and bones have been found with the skeletons of primitive and prehistoric men. These ancient people apparently thought that fossils possessed some type of supernatural power or that they would ward off "evil spirits."

Much later, fossils attracted the attention of certain early Greek and Roman philosophers. One of these men was Hippocrates, an ancient Greek who is now known as the "Father of Medicine." He and other great thinkers such as Aristotle and Herodotus recognized the similarity of fossil shells to the shells of modern creatures. Although not certain of their true origin, they at least suspected that these shells represented the remains of ancient animals. Moreover, when they found the fossilized remains of sea-dwelling creatures in the mountains they correctly concluded that the land in that area had once been covered by the sea. But most people of that long-ago time were basically superstitious and would have no part of this. Many were convinced that fossils were "freaks of nature" created by evil "plastic forces." Still others insisted that they were devices of the devil

Courtesy of Ward's Natural Science Establishment

The ancient Greeks called these fossils "thunder bolts of the gods." Actually, they represent the internal shell of an extinct squidlike animal.

which had been placed in the rocks to lead men astray.

As time passed, interest in fossils slowly grew. Each year more people picked up fossils and began to ask still more questions about them. Were these curious objects mere oddities or did they really *mean* something? And if so, *what* did they represent? Surprisingly enough, a great painter and inventor—Leonardo da Vinci—offered one of the earliest scientific answers to these questions. As a young man, Leonardo had supervised the construction of a canal in Italy. As his workmen excavated the earth they uncovered many shells, corals, and plant remains which they called to his attention. Leonardo's brilliant mind soon grasped the great significance of the laborers' discovery and he was fascinated by this unusual turn of events. He studied these ancient relics and the rocks in which they were found and soon reaffirmed the theory that fossils were evidence of past life. He said, moreover, that these fossils proved that the present relationships between lands and seas have not always existed.

But it was not until 1795 that fossils began to assume their rightful place as scientific tools. It was in that year that William "Strata" Smith, an English surveyor, was asked to lay out the route for a canal that was to be constructed in southern England. As he studied the rocks through which the canal would be dug, Smith soon became aware of a curious fact: each layer of rock contained fossils which were characteristic of that particular

rock layer and which differed from the fossils in the rocks below and above it. More important, he soon learned that these fossils could be used to identify certain rock strata wherever they occurred. Smith found that he could also use fossils to predict the location and physical characteristics of the rocks in a given area.

"Strata" Smith did not know it, but he had discovered the process of *correlation*—perhaps the most single important use of fossils. Since that time, Smith's technique of "matching" the rocks and fossils from different rock formations has been one of the basic processes in unraveling the timeless puzzles of the geologic past.

Today the process of correlation has been greatly refined. It is now known that certain species of fossils are found only in rocks of a certain age. These characteristic *index,* or *guide, fossils* are useful in identifying similar rock formations from widely scattered parts of the world. We know, for example, that dinosaurs lived only during the Mesozoic Era. Thus, when dinosaur remains are found it is usually safe to assume that the rocks containing them are Mesozoic in age.

Fossils, then, are one of the geologists' "time pieces," for they can be used to determine the time in earth history when the rock

The presence of fossils of marine animals are proof that seas once covered the areas in which these fossils are found. This reconstruction represents the sea floor of an area near Chicago in Ordovician time.

Courtesy of Field Museum of Natural History

was formed. This has application in correlation, because if the paleontologist finds rocks in Europe and Africa that contain the same fossils, he can generally assume that they were formed at the same time and thus are the same age.

Can you imagine ferns and palms growing in Antarctica? Not if you know your geography, for it is obvious that these barren, icy wastes support very little life, much less such tropical plants as these. Yet fossil ferns and coal have been found in the Antarctic. They have also been discovered on the Arctic island of Spitzbergen on the other end of the world. And on this same island, the remains of corals—which now live only in warm, shallow, sea water—are found embedded in the rocks. Modern relatives of the ferns and corals can live only in tropical or subtropical climates. Could their prehistoric ancestors have lived in such cold places? Or is it possible that the climate at the poles was different at the time these plants and animals were living?

The answer to the question lies in the fossils themselves, for most prehistoric organisms are assumed to have lived under conditions similar to those of related living forms. Consequently, the presence of corals in the Arctic suggest that this area was once covered by warm, tropical seas. Similar reasoning leads us to believe that the swamp-dwelling plants that made possible the coal deposits of Antarctica, grew under climatic conditions quite unlike those in this polar region today.

We learned earlier that the lands and seas have not always been as they are today. How do we know? Again we turn to the rocks and their fossils. By studying the occurrence and distribution of marine fossils and comparing these to the distribution of terrestrial species, we can make inferences about the positions of ancient lands and seas. This information can actually be used to draw *paleogeographic* ("ancient-geographic") *maps*. These maps show the supposed location of the continents and oceans at various times during geologic history.

Courtesy of Field Museum of Natural History

This reconstruction of a "coal forest" was made on the basis of fossils. It indicates that the climate in Illinois was once much warmer than today.

Fossils also reveal the interesting story of the development of life on our planet. The oldest known sedimentary rocks contain only the most primitive plants and animals. But as progressively younger rocks are studied, it is found that the fossils in these rocks gradually change and become increasingly similar to organisms that are living today. When properly arranged and studied in detail, these fossils clearly indicate that certain groups of plants and animals gradually changed, or *evolved,* into the more advanced species of later time.

Fortunately, fossils have practical applications as well as scientific ones. Earth scientists use fossils as clues in the search for geologic formations that may contain valuable deposits of ore, coal, or petroleum. Certain kinds of microscopic fossils are especially useful to the oil geologist. These fossils are so small that many of them are not broken by the drill bits that are used to drill oil wells. For this reason they can be brought to the surface with little damage to their original structure and can be used as markers to guide the geologist to oil-bearing rocks.

4

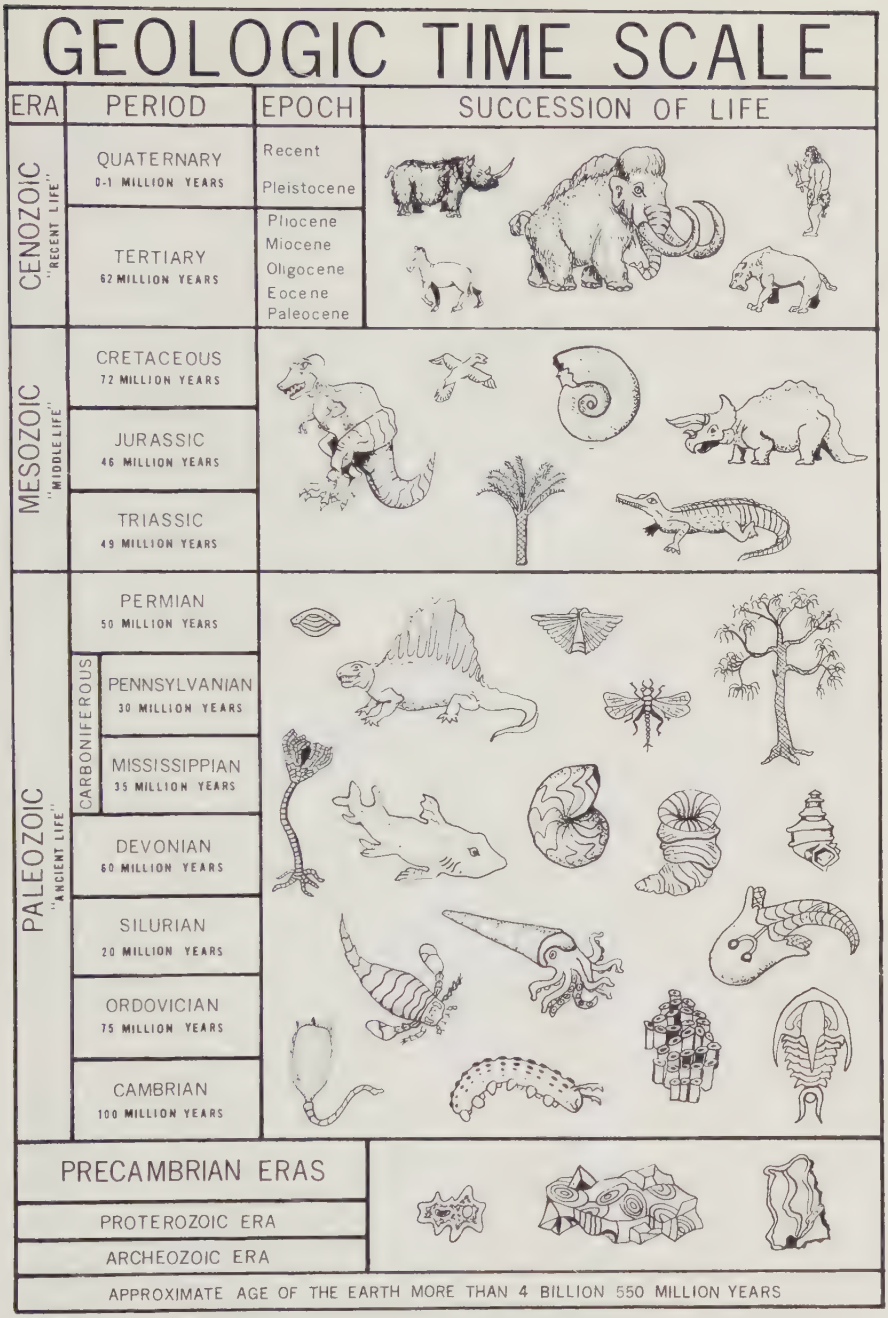
A Geological Calendar

HAVE YOU ever tried to tell someone about an event that occurred, say, several years ago, but could not recall the exact day or month in which the event took place? Most of us have had this frustrating experience, and we know that a specific date makes our story much more accurate and meaningful.

In dealing with fossils, the geologist faces this problem frequently as he traces the development of life on earth. And yet, like the historian who pieces together the story of civilization, the earth historian must have some method of relating important events to each other. And so in order to help reconstruct the major events in earth history, the geologist has devised the *Geologic Time Scale* (see page 27).

Consisting of large and small units of geologic time, this "geological calendar" is used to relate important geologic events to each other. Unlike days and years, however, the units of the time scale are of unequal duration and arbitrarily set. Therefore, it is not possible to determine the exact amount of time involved in each unit of geologic time.

The major units in the time scale are called *eras*, and represent vast portions (as much as a billion years) of geologic time. The eras have been divided into smaller units called *periods*, and the periods are further broken down into *epochs*. When these units are arranged according to their age, they form a "timetable" that provides a standard by which we can discuss the age of fossils and their surrounding rocks. By referring to the time scale, one can state that a certain dinosaur lived during the



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Mesozoic Era, in much the same way that a historian might say that a certain general fought during the American Revolution. Both "Mesozoic Era" and "American Revolution" are time terms that provide some indication as to the relative time when the animal lived or the general served.

When you look at the geologic time scale, you may ask why some of the units have such unusual names. Many of these names have been derived from Latin or Greek words and for a good reason. First, these classical languages are not subject to the change of modern languages. They are, moreover, "international" languages, for their words mean much the same thing to scientists the world around. For example, the word *Paleozoic* comes from the Greek word *palaios,* which means "ancient" and *zoikos,* pertaining to "life." Thus, by means of one universally understood word, the geologist can say that the Paleozoic Era was the time of ancient life.

The other eras are the *Archeozoic* and *Proterozoic* (usually grouped together and called the *Precambrian* eras), the *Mesozoic,* and the *Cenozoic* eras which mean "beginning-life," "fore-life," "middle-life," and "recent-life," respectively.

As noted above, each era is subdivided into periods. Most periods derive their names from the places in which rocks of that age were first studied. As an example, the Pennsylvanian Period derives its name from rock exposures in the state of Pennsylvania.

5

What Kinds of Fossils Are There?

UNTOLD BILLIONS of organisms inhabit our earth today. Not only do they live on land and in the water, but microscopic organisms even fill the very air that we breathe. In addition to their great abundance, plants and animals exist in an almost unbelievable variety of forms. They range in size from the microscopic forms that cannot be seen by the eye alone to the giant sequoia trees of California and the huge whales of the oceans. Indeed, there is hardly a place on earth where some type of life does not exist.

But life has not always been so abundant and varied. For the first few billion years of earth history, the lands were devoid of any life. However, it was present in the sea, probably in the form of primitive one-celled plants such as algae. But as time passed and our earth became a more hospitable place upon which to live, plant and animal life began to flourish and expand. Finally—about 600 million years ago—life became firmly established and we have a satisfactory fossil record from that time on.

HOW FOSSILS GET THEIR NAMES

Because there are so many kinds of plants and animals, scientists have devised a method to classify them in order to show their relationships to each other. Basically, organisms are readily divided into two major groups: the plant and animal kingdoms. But because plants and animals are so numerous and diverse, each kingdom has been extensively subdivided. The largest division of a kingdom is called a *phylum* (from the Greek word *phylon* mean-

ing a race). Each phylum is composed of a large number of organisms with certain characteristics in common. All animals with a spinal cord are assigned to the phylum Chordata (meaning that they have a *notochord* or "back-string"). Each phylum is reduced to smaller divisions called *classes*, classes are divided into *orders*, orders into *families*, families into *genera* (the plural of *genus*), and each *genus* is broken down into *species*.

The first attempt at classification began early in the eighteenth century when scientists began to catalogue all plants and animals both living and extinct. Confusion soon arose, however, for scientists working independently assigned different names to the same plant or animal. But this problem was remedied in 1758 when Carl von Linné, a Swedish naturalist who is also known as Linnaeus (the Latinized version of his name), proposed his system of *binomial nomenclature*. Under this "two-name system of naming," each plant or animal—whether living or fossil—is given two names: a *generic* (or genus) name and a *specific* (or species) name. These names are usually derived from Greek or Latin words that tell something about the plant or animal that is being described. Why Greek and Latin instead of some modern language? As mentioned earlier, these are "dead" languages and not subject to change by modern usage. In addition, they were understood by scientists all over the world. In the writing of a scientific name, the generic name should always start with a capital letter. The species name (also called the *trivial* name) should start with a lower-case letter, and both names should be italicized.

Perhaps you are familiar with the scientific name for man which is *Homo sapiens*. The first name is the genus and the second name is the species. All living men are classified as *Homo sapiens*. Although it is obvious that there are many individual variations among men, they all have certain general characteristics in common and are therefore placed in the same species.

The following examples show how man, the cat, and an oyster would be classified into these various groups.

	MAN	CAT	OYSTER
Kingdom	Animalia	Animalia	Animalia
Phylum	Chordata	Chordata	Mollusca
Class	Mammalia	Mammalia	Pelecypoda
Order	Primates	Carnivora	Isodonta
Family	Hominidae	Felidae	Ostreidae
Genus	*Homo*	*Felis*	*Ostrea*
Species	*sapiens*	*domestica*	*percassa*

CHARACTERISTICS OF THE MAJOR FOSSIL GROUPS

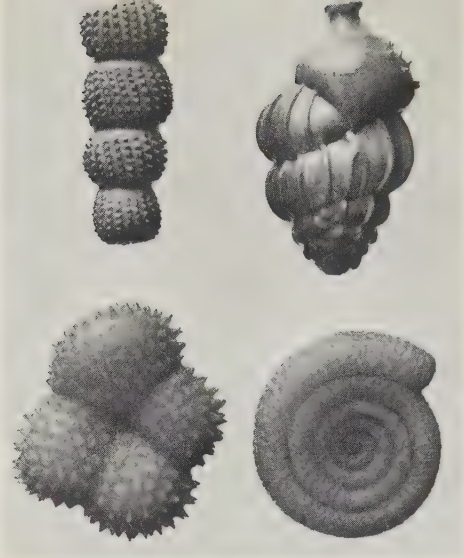
The beginning fossil collector is usually amazed by the many different plants and animals that have left some trace of their existence. In order to understand these different types of prehistoric life, it is helpful to know something about the organisms that are living today.

The following review of the major groups of plants and animals is not complete, but it will serve to show the diversity of past and present life on earth.

KINGDOM ANIMALIA

Most fossils represent the remains of animals, because their remains are more apt to be preserved than those of plants. In our discussion of the animal kingdom, emphasis will be placed on the *invertebrates*, animals without backbones, for this type of fossil is most likely to be collected. However, there is also a brief review of the *vertebrates* (animals that possess a backbone).

PHYLUM PROTOZOA. Members of this phylum all consist of a single cell. Most protozoans are microscopic in size and consist primarily of soft parts. Some, however, secrete hard shells which may become fossilized. One such group, the **Foraminifera** (for-a-min-IF-er-uh), have shells made of limy material or tiny sand grains cemented together. Commonly called "forams," these little *microfossils* are useful in identifying oil-bearing rocks. The drill



These figures are greatly enlarged models of typical foraminifers that are valuable as microfossils.

Courtesy of Field Museum of Natural History

bits used in drilling for oil will destroy larger fossils, but the tiny shells of the forams can be brought to the surface intact. They lived as far back as the Ordovician Period, about 500 million years ago (see the Geologic Time Scale). Forams are also very abundant in modern seas.

PHYLUM PORIFERA. Members of this phylum, commonly called sponges, are many-celled animals that live mainly in the sea where they are attached to the bottom. The soft body of a sponge may contain small hard parts called *spicules* and these are commonly fossilized. But despite their long geologic history (from the Cambrian Period until today) sponge fossils are usually poorly preserved and difficult to recognize.

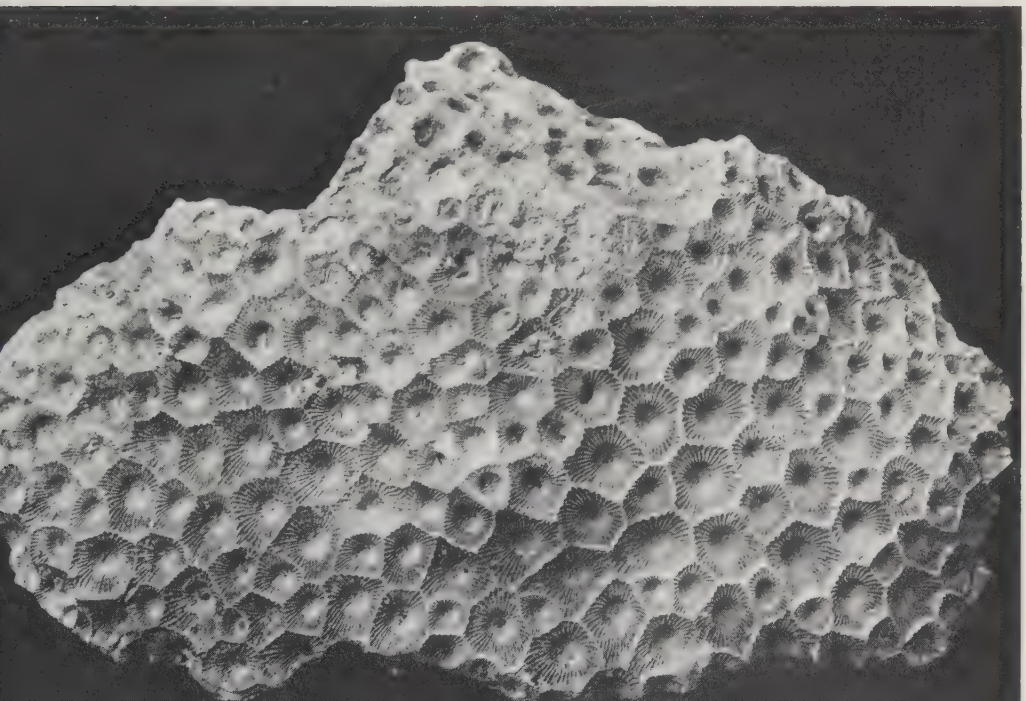
PHYLUM COELENTERATA. The coelenterates are a large group of *aquatic* (water-dwelling) animals that include the jellyfish, sea anemones, and corals. Most coelenterates lack hard parts and rarely form fossils. But one group—the corals, members of the **class Anthozoa**—grow an external stony skeleton that is commonly fossilized. The *colonial corals* grow together in colonies composed of individual corals whose skeletons are attached to each other. These colonies may be branching or massive and at some places

Courtesy of Field Museum of Natural History

Fossil sponges were common in the seas of Paleozoic time

Colonial corals consist of the skeletons of many individual corals that grow together as a single colony

Courtesy of Field Museum of Natural History



Solitary coral fossils grew as single individuals. They are common in certain Paleozoic rocks.

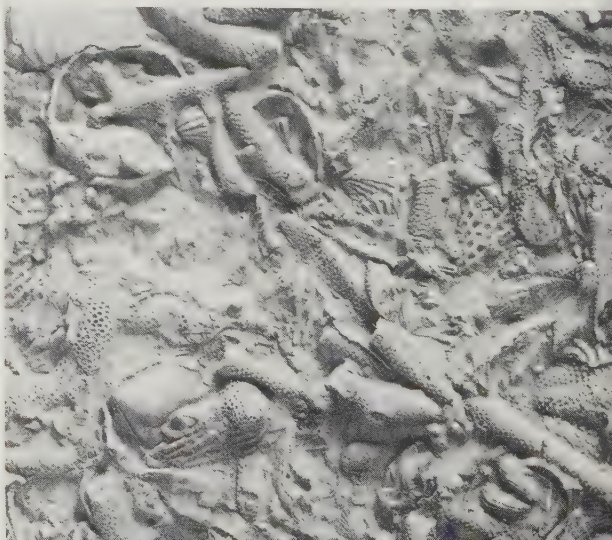
Courtesy of Field Museum of Natural History

they form coral reefs that are hundreds of miles long. *Solitary corals* grow as single individuals and may be horn-, cup-, or tube-shaped. They range from almost microscopic in size to more than two feet in length.

Because of their durable skeletons, coral remains are found in rocks ranging from Ordovician to Recent in age.

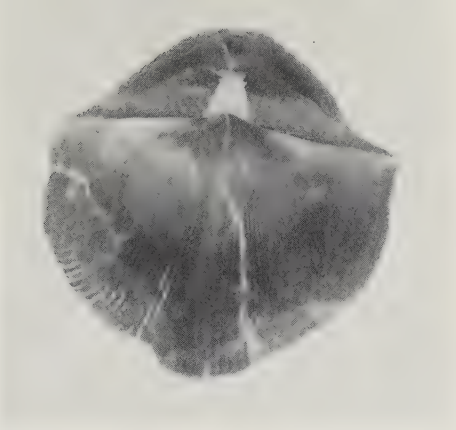
PHYLUM BRYOZOA. Most bryozoans are tiny, colonial, marine animals. They secrete a small *calcareous* (limy) skeleton that is commonly fossilized. Some of the colonies consist of a simple chainlike series of tubes, but they may also be leaf-, fan-, or ball-shaped.

Bryozoans are rather common as fossils, especially in Paleozoic



Bryozoans found in this slab of Ordovician limestone are typical Paleozoic fossils

Courtesy of Smithsonian Institution



This brachiopod, or "lampshell," was common during the Devonian Period
Courtesy of Malick's Fossils

rocks. They are sometimes found encrusted on other fossils and for this reason they are often called "moss animals." Bryozoans have lived since Ordovician time and are abundant in modern seas.

PHYLUM BRACHIOPODA. These are the "lampshells"—a group that superficially resembles the clams. Both clams and brachiopods have a shell composed of two parts or *valves*. Most clam valves are the same shape and size and are mirror images of each other.

Brachiopod shells vary greatly in appearance. Some are circular and smooth; others are elongated and bear knobs and spines. In size, they may range from less than a fourth of an inch to several inches across. The composition of the shell may be phosphate or a horny material called *chitin*, a substance similar in composition to our fingernails. But most have calcareous shells that are readily fossilized and for this reason they have left a good fossil record from the Cambrian Period on.

Principal parts of a typical pelecypod shell: (a) exterior view (b) interior view

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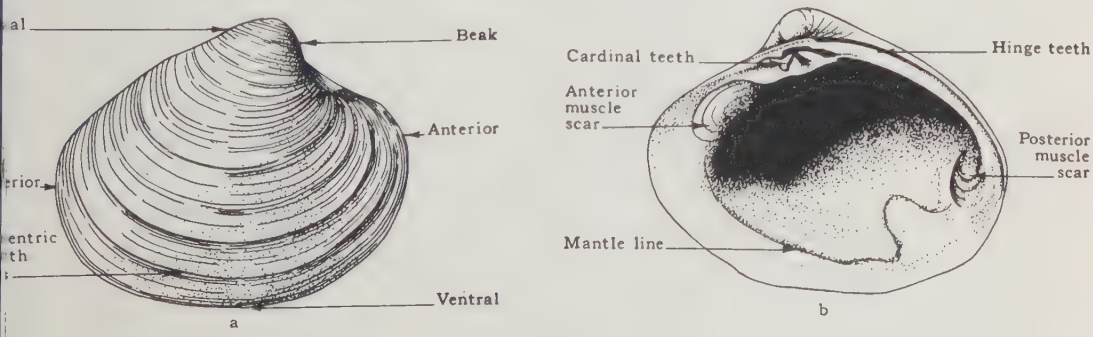


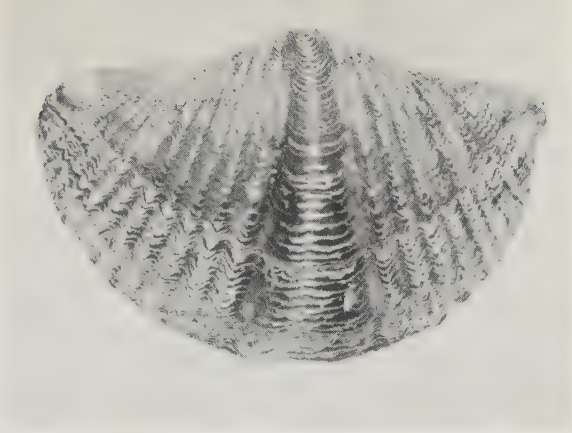
"Lampshells" are not common in today's oceans, but during Early Paleozoic time they were the most abundant shellfish on earth. Consequently, brachiopods of many sizes and shapes are found as fossils in Paleozoic rocks.

PHYLUM MOLLUSCA. The mollusks are a large group of aquatic and terrestrial animals. This phylum includes such familiar forms as the snails, slugs, clams, oysters, squids, and octopuses. The soft parts of most mollusks are covered by a hard calcareous shell. But some mollusks (the slugs) have no shell, and others—for example, the squids—have an internal shell. Because of their hard parts, their great abundance and variety, and their long geologic history, mollusks are especially common as fossils. Of the five classes of phylum Mollusca, only three will be reviewed here.

Members of the **class Pelecypoda** have a shell composed of two calcareous valves and include the clams, mussels, scallops, and oysters. They are found in both fresh and salt water where they may be attached, burrow into the bottom, or creep about by means of a hatchet-shaped foot. One group, the scallops, is free-swimming. They swim by opening the valves and snapping them shut. This forces the water out of the shell in a strong stream. The animal actually moves by jet propulsion!

The shells of these Permian pelecypods have been replaced by the mineral, silica. Their presence in the mountains of west Texas indicates that the sea covered this area during Permian time.

Courtesy of Smithsonian Institution



The growth lines where shell was added as the animal grew are clearly visible on this Middle Devonian brachiopod

Courtesy of Malick's Fossils

Unlike the brachiopods, pelecypod valves are of equal size and mirror images of each other, one on the left and the other on the right. Each shell also has a *beak* that points forward. This represents the spot where the shell began to grow. Along the top edge of each valve there may be several *teeth* and *sockets*. These fit into similar structures on the opposite valve to form a *hinge*. The outside of the shell is usually marked by ribs, spines, knobs, and *growth lines*. The latter show the size of the shell during various periods of growth.

Many fossil pelecypods are found as casts and molds, but fossil shells composed of original shell material can also be found. Although pelecypods first appeared during the Ordovician Period, they are especially common as fossils in rocks of Late Paleozoic, Mesozoic, and Cenozoic age.

Commonly called snails, members of the **class Gastropoda** have adapted themselves to life in the sea, in fresh water, and on the

This fossil cast formed when the shell of a large clam became filled with sediment that hardened. Later the shell dissolved.

Courtesy of Malick's Fossils

land. The typical gastropod carries a coiled, unchambered shell on its back. When danger threatens, the snail retreats into the safety of its limy house. Some species even possess a piece of shell that fits the shell opening like a door. The shell is generally coiled in a spiral, but some are cone-shaped, cylindrical, flat, or turreted. Most specimens have various types of ridges, spines, and knobs on the exterior, but some shells are quite smooth.

Despite their abundance in ancient seas, gastropod shells were easily destroyed because they were composed largely of a relatively soluble mineral called *aragonite*. In some cases, however, the shell became filled with sediment after the snail died and its soft parts decayed. When the outer shell weathered from around the solidified sediment, this interior filling was left as an internal mold. Although common as fossils, these molds are often difficult to identify, for they do not show the outer form of the shell.

The earliest known snails lived during the Cambrian Period, more than 500 million years ago. Today they are abundant in all parts of the world.

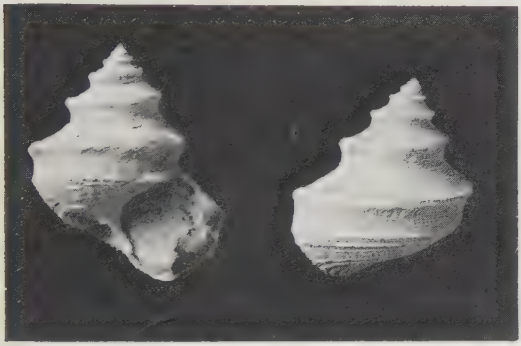
Members of **class Cephalopoda** were more numerous in the past than they are today. These are the most advanced invertebrates and have a highly developed nervous system. Their large eyes are much like those of vertebrates and they have well-developed hearing organs.

The creature's mouth is surrounded by long tentacles commonly armed with suckers. Like the scallop, cephalopods move by jet propulsion when water is forced out of a tube beneath the animal's head. Cephalopods can also eject a colored fluid, or "ink," through this tube. This creates a watery "smoke screen" behind which they can escape their enemies.

Most fossil cephalopods had a calcareous external shell. Earlier forms had slender, cone-shaped shells, but as time passed their shells became curved or coiled. Whether loosely or tightly coiled, the shell is almost always in a flat coil and does not spiral upward like that of a gastropod.

Descendants of these fossil marine gastropods thrive in waters of modern seas. The cast (left) was formed in a shell similar to the one on the right.

Courtesy of Malick's Fossils

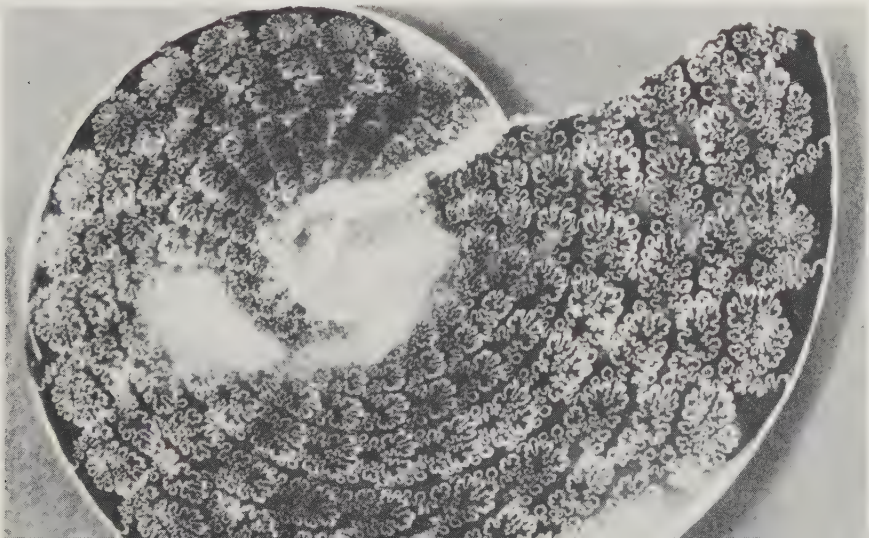


The shells of these Pennsylvanian gastropods have been especially well preserved

Courtesy of Smithsonian Institution

The suture patterns of this Cretaceous ammonite are clearly visible. This type of fossil is characteristic of Mesozoic rocks.

Courtesy of Ward's Natural Science Establishment



The living animal occupied only the end portion of the fossil shell. As the animal grew, it sealed the *living chamber* off from the rest of the shell. This was done by secreting pearly, calcareous partitions called *septa* which divide the typical cephalopod shell into a series of *chambers*. The pattern of the septa can commonly be seen on fossil cephalopods, and this *suture pattern* helps to distinguish one species from another.

Cephalopods have apparently always been the giants among the animals without backbones. One uncoiled cephalopod of Ordovician time was as much as fifteen feet long. In modern seas, there are giant squids that measure almost 50 feet when their tentacles are extended!

Straight cephalopods first appeared in Cambrian time and were abundant during the Ordovician and Silurian Periods. Coiled forms became fairly common in later Paleozoic time, but were extremely numerous during the Mesozoic Era.

PHYLUM ANNELIDA. The *annelids*, or segmented worms, have a long geologic history and they may have been living during Precambrian time. Most, like the common earthworm, are composed primarily of soft parts. Even so, they are represented by various fossils such as tubes, trails, castings, and tooth-bearing jaw structures.

Although they became extinct at the close of the Permian Period, trilobites are abundant in many Paleozoic rocks throughout the world

Courtesy of Geological Enterprises

PHYLUM ARTHROPODA. Characteristically segmented, joint-legged creatures, the arthropods are among the most abundant animals on earth. They exist on land, in fresh and salt water, and in the air—in fact, you are likely to find arthropods any place where life can exist. This great group of organisms contains such familiar forms as the shrimps, crabs, crayfish, barnacles, insects, and spiders. Despite the fact that arthropods outnumber all other animals today, only a few groups are commonly found as fossils. Of these only the **trilobites**, **ostracodes**, and **eurypterids** are briefly described below.

Although they have been extinct since the close of the Paleozoic Era, **trilobites**—because of their unique form and relative scarcity—are highly-prized fossils to amateur collectors and professional geologists alike. Two grooves extending down the back of the animal divide its body into three lobes, and this tri-lobed appearance gives the animal its name. From front to back, the body is composed of a number of serially arranged segments, and in life a pair of jointed legs grew from each side of most of these segments. Because of their softness, the legs were seldom preserved.

Like the crabs and lobsters to which they are distant "cousins," the trilobites lived in the sea and their backs were covered by a protective coat of chitin. This chitinous exoskeleton preserved well, and this accounts for the abundance of trilobites in certain Lower Paleozoic rocks. As they grew larger, trilobites *molted* their armor much as a snake sheds its skin. If these molts, or immature shells, were preserved, then each animal could have provided several fossils.

In some species the body segments are arranged in such a manner as to permit the trilobites to roll up into a ball. This was probably done in order to protect the animal's soft underside which was apparently not covered by a hard covering.

Trilobites flourished during Cambrian, Ordovician, and Silurian time and became extinct near the end of the Permian Period.

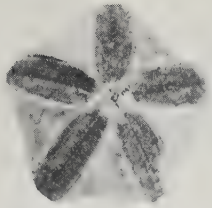
Courtesy of Smithsonian Institution

The eurypterids were scorpion-like creatures which grew to be as much as nine feet long. This specimen was collected in rocks of Silurian age near Buffalo, New York.

The **ostracodes** are minute, bean-shaped arthropods which externally resemble small clams. But the little animal that lives in the small two-valved shell has the jointed legs and segmented body of the typical arthropod. Because they are so small, their shells are not normally broken by the drill bits used in the search for oil. For this reason, ostracodes are especially useful as microfossils for the petroleum geologist.

How would you like to meet a scorpion nine feet long? The **eurypterids**, another group of extinct arthropods, were scorpion-like creatures which grew to be this size. These creatures, which are closely related to the spiders, scorpions, and "horseshoe" crabs, lived from Early Ordovician to Permian time. In general, they are relatively rare as fossils.

PHYLUM ECHINODERMATA. The echinoderms, or "spiny-skins," are a large group of sea-dwellers which include the starfish,



In some areas blastoids, or "sea buds," are called fossil acorns. This species is an excellent guide fossil for Mississippian rocks.

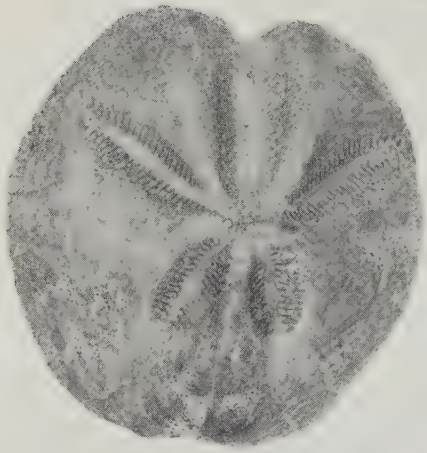
Courtesy of Malick's Fossils

sea urchins, sand dollars, sea lilies, and sea cucumbers. These are rather complex creatures with a skeleton composed of numerous calcareous plates which are intricately fitted together. Many fossil echinoderms had a long, flexible jointed stem by which they were attached to some foreign object or to the ocean bottom. However, most modern forms are unattached and move freely over the floor of the sea.

The most common stalked fossil echinoderms are the **blastoids** and the **crinoids**. The blastoids, or "sea buds," are members of the **class Blastoidea** and typically have a symmetrical, often budlike,

The flower-like nature of the crinoid, or "sea lily," is easily seen on this specimen. The stem is composed of a series of button-like disks.

Courtesy of Smithsonian Institution



When alive, this heart-shaped fossil sea urchin was covered with spines

Courtesy of Malick's Fossils

body called the *calyx*. The calyx is composed of thirteen plates and there are five food grooves running downward from the mouth which is located on top. Blastoids occur in rocks ranging from Ordovician to Permian in age, but were especially abundant during the Mississippian Period.

The members of **class Crinoidea** (the **crinoids**) are sometimes called "sea lilies," but they are animals rather than plants. Their globe- or cup-shaped bodies are generally supported by a stem or stalk. The stem consists of a series of button-like discs in the center of which there is usually a round or star-shaped opening. The stem is attached to the sea floor by a stony anchor or rootlike arms.

The crinoid calyx is composed of intricately fitted, calcareous plates. The *mouth*, located on top of the calyx, is surrounded by radiating, jointed arms which sweep food into it.

Although the disc-shaped segments of crinoid stems are among the most common fossils in Paleozoic rocks, a complete crinoid calyx is a very rare fossil. This is because the body plates fall apart when the animal dies and become scattered about the sea floor.

Crinoids are relatively rare today, being confined mainly to the deeper parts of the ocean. But during Paleozoic time these sea lilies were extremely abundant in the warm shallow seas that covered much of North America.

The most common free-moving and unattached echinoderms

are the starfish and the sea urchins. But only the latter—members of **class Echinoidea**—are common as fossils. Echinoids are disc-, heart-, or biscuit-shaped echinoderms with bodies consisting of closely fitted, calcareous plates. The outside of the *test*, or shell, is commonly covered with spines which are used to support the body, provide protection, and aid in locomotion. Because of their spiny appearance, sea urchins are sometimes called "pincushions of the sea."

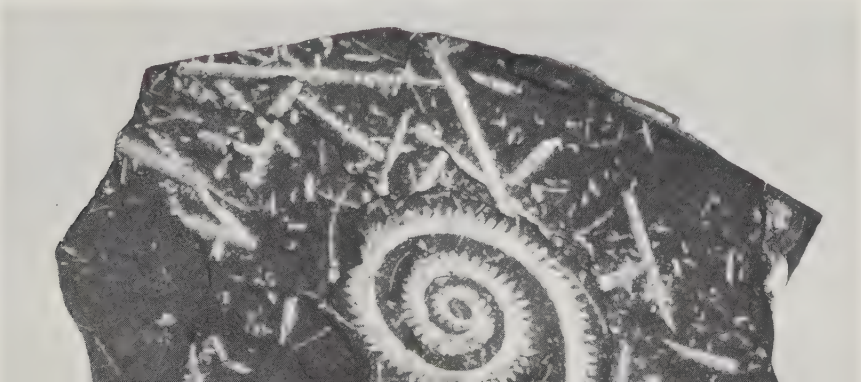
Echinoids range from Ordovician to Recent in age, and their spines, plates, and bodies are especially abundant as fossils in certain rocks of Cretaceous age.

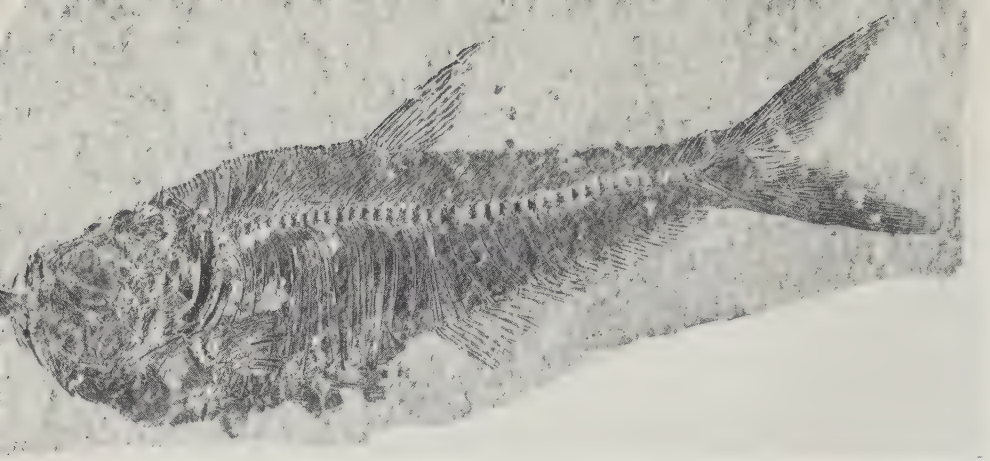
PHYLUM CHORDATA. The chordates are the most advanced animals that occur as fossils. They are characterized by a well-developed nervous system and a body supported by a bony or cartilaginous *notochord* or *spinal column*. Among the various chordates, only the *graptolites* and the *vertebrates* have left a satisfactory fossil record.

The *graptolites* are an extinct group of marine animals that were especially abundant during the Ordovician and Silurian Periods. They have been extinct since Mississippian time. Although they were originally classified as coelenterates or bryozoans, they are now considered to be lower chordates.

Graptolites, a primitive type of chordate animal, are especially numerous in certain Lower Paleozoic rocks

Courtesy of Ward's Natural Science Establishment





W. T. Lee, courtesy of United States Geological Survey

Fossil fish are especially well preserved in the Tertiary-aged Green River Formation in western Wyoming

The animals grew in colonies composed of small chitinous cups supported by slender stems. In some species a number of the stems were attached together, but in others, the stems were attached to a round float.

As fossils, they are usually found as carbon films and resemble small single- or double-edged saw blades. Each "tooth" on the "saw blade" represents a little cup in which a single graptolite animal lived and all of the cups together make up the graptolite colony.

Although vertebrate fossils are not collected by most rockhounds, the back-boned animals include such interesting and well-known fossils as the dinosaurs, woolly mammoths, and saber-toothed cats. For this reason, the more important vertebrate classes are briefly reviewed here in order that the reader may have some understanding of these important animals.

Members of the **superclass Pisces** are commonly called fishes and are the simplest of the vertebrates. Fishes belonging to **class Agnatha** are primitive, jawless, finless creatures represented by such living forms as the lamprey eel and the hagfish. The earliest known vertebrates belong to this class and they were small fish called **ostracoderms**. Their bodies were armored with small bony plates which have been found as fossils.

Another extinct group, **class Placodermi**, were also armored, but they possessed both jaws and fins. Certain of the placoderms resembled sharks, and some of them grew to be as much as 30 feet in length.

The living sharks, skates, and rays belong to **class Chondrichthyes**. Abundant in marine waters today, they are characterized by skeletons which are composed of cartilage rather than bone.

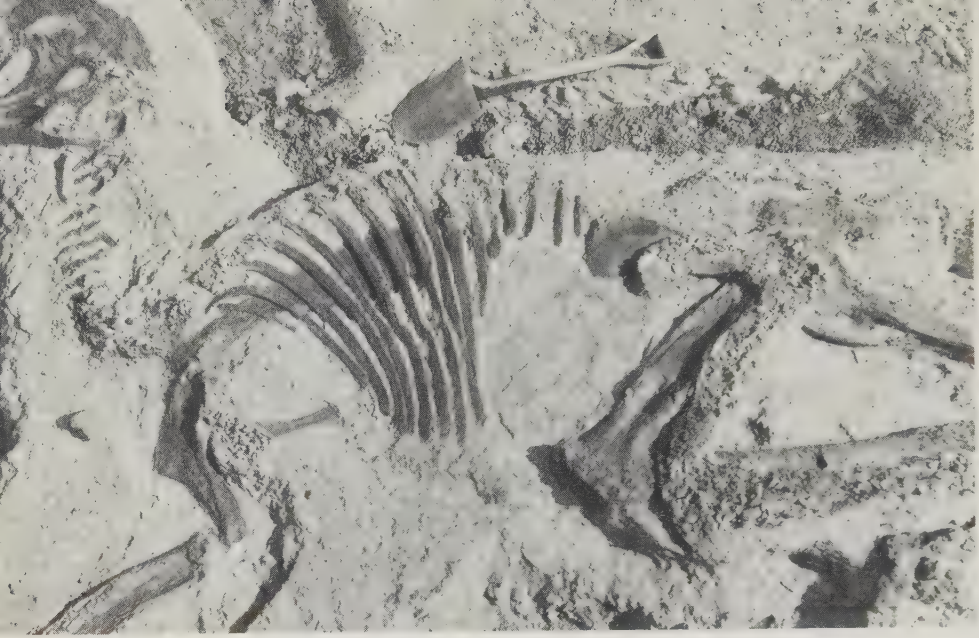
Class Osteichthyes includes the true bony fishes—the most highly developed and abundant of all fishes. In addition to an internal bony skeleton, they have well-developed jaws, an air bladder, and, typically, an external covering of overlapping scales. Trout, perch, salmon, and bass are typical of this group.

The **superclass Tetrapoda** has been established to distinguish the members of **superclass Pisces** from the non-fishlike and more advanced vertebrates. Tetrapods characteristically possess lungs, a three- or four-chambered heart, and paired appendages. Typical members of this group include amphibians (frogs and toads), reptiles (snakes and lizards), mammals (men, dogs, cows), and the birds.

Class Amphibia is made up of cold-blooded animals that spend most of their life on land, but during their early stages of development they live in the water. The earliest terrestrial vertebrates, the amphibians, first appeared in Late Devonian time.

Unlike amphibians, members of **class Reptilia** have become adapted to permanent life on land. Reptiles were formerly much more abundant than they are today, and they assumed many different shapes and sizes in the geologic past. Notable among ancient reptiles were the unusual terrestrial reptiles called **dinosaurs**; ranging from a few feet to as much as 85 feet in length and from a few pounds to perhaps 50 tons in weight. The now-extinct "terrible-lizards" dominated life of the Mesozoic Era for about 145 million years.

Some dinosaurs were *carnivorous* (meat-eaters), but most were



C. M. Sternberg, courtesy National Museum of Canada

Dinosaurs, such as this duck-billed form found in Canada, are the best known of all reptile fossils

herbivorous (plant-eaters). There were forms that walked on their hind legs and others that walked on all fours. In short, the dinosaurs were one of the most unusual groups of creatures to ever inhabit the earth.

Other interesting Mesozoic reptiles include the flying forms called **pterosaurs**. Some of these "flying dragons" had a wingspread of as much as 27 feet. Reptiles also dominated Mesozoic seas. Large swimming reptiles such as the fishlike **ichthyosaurs** and the peculiar **plesiosaurs** were especially numerous. With such an abundance and diversity of reptilian creatures it is not surprising that the Mesozoic Era has been called the "Age of Reptiles."

Birds, which have been assigned to **class Aves**, are seldom found as fossils because of the fragile nature of their bodies. The most ancient bird yet found was collected from Upper Jurassic rocks in Germany. Given the name *Archeopteryx* (literally "ancient-wing"), this primitive bird was little more than a reptile with feathers. It was about the size of a pigeon, possessed a toothed bill, lizard-like tail, and other definitely reptilian characteristics.

Courtesy of Smithsonian Institution

This skeleton is typical of the great flying reptiles of the Mesozoic Era

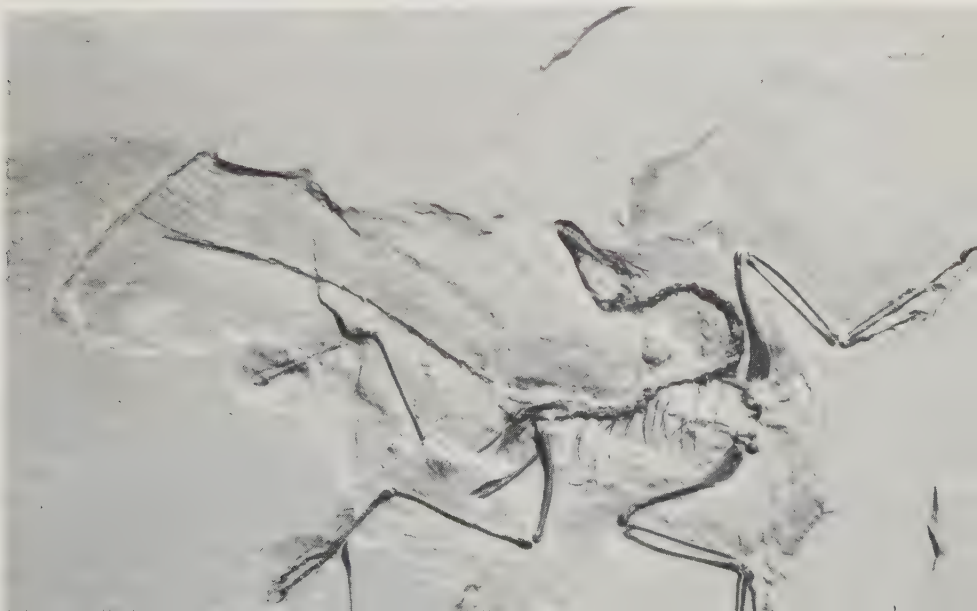
During the Cretaceous Period, birds underwent rapid development and by the Tertiary Period some flightless birds stood as much as six feet tall. Most of our present-day forms had developed by the end of Tertiary time.

The members of **class Mammalia** are the most advanced of all vertebrates. The typical mammal is born alive, fed with milk from the mother's breast, breathes by means of lungs, and is warm-blooded. Included in this class are swimming forms such as the whale, flying forms like the bat, and a host of terrestrial mammals including horses, dogs, cats, and man.

Although first appearing in Jurassic time, the mammals under-

When first discovered, this ancient bird was believed to have been a flying reptile. Note, however, the impression of the feathers in the rock.

Courtesy of American Museum of Natural History



went their greatest expansion during the Tertiary Period—the "Age of Mammals." During Tertiary and Pleistocene time, certain mammals became extremely large and assumed many bizarre shapes. Although most of these unusual forms were doomed to early extinction, many of them are well known from their fossils. These include the elephant-like mastodons and woolly mammoths, the saber-toothed cats, horses, camels, huge pigs, and giant rhinoceroses. Man, a relative newcomer on the geologic scene, probably did not appear until Pleistocene time.

KINGDOM PLANTAE

Although plant fossils are usually fragmental and difficult to identify, plants have left an adequate fossil record that tells much about their development on earth. Only the major groups of plants —commonly called *subkingdoms*—will be considered here.

SUBKINGDOM THALLOPHYTA. The **thallophytes** are the simplest of all plants and were probably the first living things on earth. Ranging from Precambrian to Recent in age, this group includes algae, fungi, and the microscopic diatoms. Because they are so small, the latter commonly occur as microfossils.

Reconstruction of a scene at a Pleistocene water hole in Los Angeles. Seen here are giant vultures, saber-tooth cats, and ground sloths. Mammoths and wolves can be seen in the background.

Courtesy of American Museum of Natural History

Courtesy of Smithsonian Institution

This Precambrian algae (left) is more than a billion years old. The fossil impression (right) is of a leaf from a tree that lived in Colorado during Middle Tertiary time.

SUBKINGDOM EMBRYOPHYTA. These plants are considerably more advanced than the thallophytes. In this subkingdom are the **division Bryophyta** (the mosses) and **division Tracheophyta,** which includes most living and fossil plants. (A *division* in the plant kingdom is similar to a *phylum* in the animal kingdom.)

Common present-day tracheophytes include the ferns, evergreens, flowering plants, and hardwood trees. Among the better-known fossil tracheophytes are the cycads, ginkgoes, and "coal plants" such as the scale trees and club mosses. The "coal plants" are commonly found associated with the great coal deposits of the Mississippian and Pennsylvanian Periods.

In this chapter we have only caught a glimpse of the wonderful world of life. Hopefully, you will read other books that discuss living and fossil organisms in greater detail. Some of these are listed on page 62 of this book. Meanwhile, we have learned enough about plants and animals to see how varied they are and how they have developed through time.

6

Finding Fossils

NOT ALL famous fossil finds have been made by professional fossil hunters. The first evidence of dinosaurs in the United States was uncovered by a New England farmer in 1802. And in 1811, a twelve-year-old English girl named Mary Anning discovered the first ichthyosaur—an extinct fishlike swimming reptile. Nor did Mary stop with her first great fossil find. In 1821 she found the remains of another large prehistoric sea reptile called a plesiosaur. Seven years later Mary made her third remarkable fossil discovery. She found, for the first time in England, the skeleton of one of the curious flying reptiles known as the pterosaurs or "wing lizards."

Even now, similar "amateur" discoveries continue to be made. As recently as 1960, three teen-age boys unearthed a previously unknown flying reptile in an abandoned quarry in New Jersey. This fossil skeleton looked like a cross between a lizard and a large dragonfly and represented an animal that glided on wing-like surfaces formed by its elongated ribs. It was an important find, for this creature apparently lived some 15 million years earlier than any other known flying reptile and about 60 million years before the first bird appeared. Thus, although not scientists, the New England farmer, Mary Anning, and the New Jersey school boys, did much to advance scientific knowledge.

How can you join in the search for fossil treasure? Luckily, it is easy to get started, for there are good fossil hunting grounds in many states. Better yet, the equipment that you need is not expensive. In fact, you can probably find the basic collecting items lying around your house.

Fossil collecting can be an inexpensive and exciting hobby

The first thing that you need in your fossil hunter's kit is a hammer. Almost any type hammer will do at first. But as you graduate from a "pebble-pup" to a full-fledged "rockhound," you may want to get a geologist's hammer. Known also as prospector's or mineralogist's picks, these hammers are of two types. One kind has a square head on one end and a chisel-like blade on the other end. It is similar to the hammers used by stonemasons and bricklayers. The other type has a pointed pick end instead of the chisel end. The square head of the hammer is useful in breaking and chipping harder rocks, while the chisel or pick end is good for prying, digging, and splitting softer rocks. In addition to the hammer, you will need a couple of cold chisels (½ and 1 inch widths), and a small sharp punch. These will come in handy when fossils must be chipped out of the surrounding rock. A putty knife or an old wide-blade dinner knife is useful in working in loose soil.

A knapsack or small canvas shoulder bag can be used to carry both fossils and collecting gear. In your bag you should have a good supply of newspaper, some small paper bags, tissue paper,

and perhaps some cotton. These wrapping materials can be used to protect your fossils on the trip back home. Some small paper labels (about two by three inches) should also be included. These can be used to record the collecting locality, the date of collection, and the collector's name. A properly completed label should be placed inside each bag of fossils taken from the locality described on the label.

Finally, you will need a pencil, a small pocket notebook, and some type of map. Use these to record the location of the collecting spot in the notebook—never rely on memory. A highway or county map can be used to find the geographic location of each fossil locality. Such maps can usually be obtained for each county of the state and can probably be ordered from your state highway department.

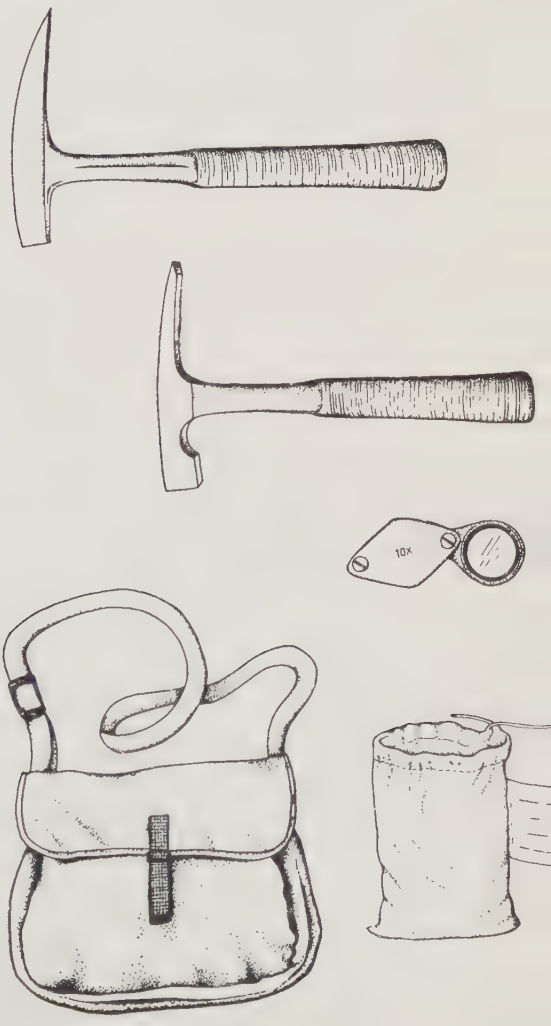
Although not absolutely necessary, you may want to get a magnifying glass (about 10 power) for examining smaller fossils and an inexpensive compass to permit more accurate location of collecting areas. In addition, any publications on fossil collecting in your state will be helpful. Many states have published nontechnical, educational literature on fossils. Local libraries should have such publications for their state or be able to provide the address of the state Geological Survey or Bureau of Mines.

Now that you are equipped for a fossil hunting expedition, where do you look? It has been said that locating fossils is 90 per cent luck and 10 per cent "know-how." But that 10 per cent "know-how" is quite important to the beginning collector. Indeed, if you look in the wrong places, even 100 per cent luck won't help you!

In general, the best place to find fossils is where they have been collected previously, and the best way to find such a place is to ask questions. Start with any local "rockhounds" or amateur collectors that you know. They will be more than glad to share

their collecting experiences with you. The local library or museum may also know of good fossil hunting spots. Or ask a local professional geologist or a biology or geology professor in a nearby college or university. Through these contacts you may be able to take your first trip with an experienced collector or with an organized group such as a rock and mineral club or a museum class. This will help you to recognize the type of locality where fossils are most likely to be found.

Even the rankest amateur soon learns that most fossils are found in marine sedimentary rocks. Most such rocks are formed



The items shown here are the major tools of the fossil collector

Reproduced by permission from Fossils: An Introduction to Prehistoric Life *by William H. Matthews III, Barnes and Noble, Inc.*

from sediments that were deposited under circumstances that were favorable for organisms during life. In addition, these same salt-water conditions facilitated preservation of the remains after death. Limestones, limy shales, and certain types of sandstones are typical rocks of this type. You should look particularly for areas where rocks formed from marine sediments have not been greatly disturbed or altered by heat, pressure, and other physical and chemical changes. If the rocks appear to have undergone a great deal of folding or fracturing, it is quite possible that this action may have damaged or destroyed any fossils that might have been present.

Rock quarries are good places to look for fossils. Here the rock exposures are relatively fresh, but they have usually been weathered enough to loosen some of the fossils. Softer beds of shale between layers of limestone and sandstone are especially likely to yield fossils. And do not overlook sand and gravel quarries—fine specimens of petrified wood and the bones of large mammals are commonly found in sand and gravel pits. But before you collect from a quarry—or *any* private property—be

In some areas fossils are literally scattered over the ground. Brachiopods, corals, and crinoids are seen here in a shale of Devonian age.

Courtesy of Ward's Natural Science Establishment

Courtesy of American Museum of Natural History

This previously unknown fossil flying reptile was discovered by amateur collectors in 1960

sure that you get the permission of the owners. Once on their land, treat it as you would your own. This will insure that you and other collectors will be welcome to return again.

Fresh cuts made for railroad and highway construction often prove to be fruitful hunting grounds. Rocks exposed in this way are usually fairly well weathered and in their original position. Be sure, of course, to be watchful of passing cars and trains.

Some of the finest fossil collecting is to be found in canyons, gullies, and stream beds. Because their sides are continually undergoing weathering and stream erosion, new specimens are uncovered year after year and may be picked up easily.

If there are abandoned coal mines nearby, look at the dumps of waste rock around the shafts. Many fine plant specimens can be found in some of these places. Fossil animal remains may also be collected at some of these waste piles.

Suppose that you find a river bank or some other area that meets the qualifications discussed above. What next? First, get as close to the ground as possible and carefully examine the surface. As your eyes scan the ground be alert for pieces of rock fragments that contain leaf impressions, bits of shell, or bone fragments. These are the clues that may lead to *your* big fossil discovery.

Once the clues have been found, then the detective work begins in earnest. The object, now, is to take your time and cover the ground thoroughly. Remember, the closer you look the more fossils you are likely to find. And above all, be patient. Some of the finest specimens that you collect may well have been overlooked by some less careful fossil hunter.

Now let us assume that your sleuthing has paid off and that your clues have led to a rich cache of fossils. You must now get them out of the rock, into your kit, and safely home. The task will be easy if the fossils have been freed by weathering or occur in loose soil. These can be dug out with a knife or the sharp end of your hammer. At times, however, it may be necessary to chip away the rock around the fossil or loosen it with a chisel. If this must be done, work slowly and cautiously so as not to damage the specimen. More important, if it is necessary to do a lot of hammering and chiseling, it is wise to wear safety goggles to protect your eyes.

To insure a safe trip home, fossils should be wrapped in the field with newspaper, tissue, or aluminum foil. Sandwich bags and small plastic pill vials are especially good for smaller specimens. As an extra precaution, place the larger fossils in the bottom of the collecting bag and more fragile specimens on top of these.

By observing the above simple "how's" and "where's" of fossil collecting you should soon be able to hunt fossils like a veteran "rockhound."

7

Your Fossil Collection

THE HUNTING was good and you are back home—tired but happy. You have collected some fine specimens and brought them safely home. Now, what are you going to do with them? You could leave them in the collecting bag until you go hunting again. Or perhaps you could dump them into a corner of your room until someone gets tired of looking at them and throws them in the trash can. You *could*—but not if you are a good collector.

The experienced fossil hunter wants to put his fossils on display for all to see and enjoy. He has learned that one of the most satisfying parts of his hobby is sharing his collection with others. But he has also learned that fossils are not found in a "museum-ready" condition. Instead, they must be cleaned and prepared for display.

First, the fossils should be washed to remove loose soil and rock layers which may be hiding part of the specimen. If they are heavily encrusted with dirt, it may be advisable to soak them in water overnight. You can then clean the surface of the fossil with various chipping and scraping tools. Ice picks, cold chisels, wire brushes, and fine needles may be used, according to the size and fragility of the specimen. Work cautiously and take your time. Remember that a fossil that has been preserved in the rocks for hundreds of millions of years can be ruined with one careless tap of a hammer!

Occasionally you will find a specimen that crumbles easily after exposure to the atmosphere. These, and other fragile fos-

sils, can be protected with a coating of clear plastic spray or clear nail polish.

After the fossils have been cleaned and prepared, they should be placed in trays or boxes. A candy box, with partitions in it, or an egg carton make good inexpensive holders. Match cartons, shoe boxes, and cigar boxes are also good containers in which to store fossils.

Now that your fossils have been cleaned and placed in a proper container, they are ready to be identified. This is the final step in any fossil collecting expedition and the first step in establishing a worthwhile fossil collection.

Before trying to identify your material, it may be helpful to refer to Chapter 5 of this book. This will enable you to refresh your understanding of the way fossils are classified. It will also prove helpful to compare your specimens with some of the fossils that are illustrated there. But since this is not an "identification" book, you will probably have to compare your fossils with illustrations in reference books or encyclopedias in your school or public library. A number of these are listed in the "For Further Reading" section.

Do not be discouraged if you are unable to identify every specimen the very first time that you try. Most professionals are not able to do this either. If possible, begin by showing your fossils to an experienced collector. Better yet, show them to a geology professor if there is a college or university near you. The biology or earth science teacher in your school will probably also be able to help you.

If there is a museum of natural history in your city, compare your specimens with those in the museum collections. It is also helpful to talk to some of the museum employees, for they may make suggestions that will save you much time.

Additional information may also be obtained from the United States Geological Survey in Washington, D. C., and the Bureau

of Mines or Geological Survey of your home state. As mentioned earlier, about half of the states have prepared educational material that is useful to amateur collectors.

Once the specimens have been identified, the next step is to provide them with a permanent label. These can be typed or written in ink on heavy white paper or cards.

It is also a good idea to keep some form of permanent record book, in case the label should become lost. The number assigned to the fossil and all other information on the label should be entered in the log book. A spiral-bound or loose-leaf notebook is good for this purpose.

Sometimes a fossil and its label will become separated. Consequently, the same number that is written on the label should also be placed on the fossil as well as in the log book. This number should be written on the specimen in India ink, preferably in some inconspicuous place. If the surface of the fossil is coarse or porous, paint a small white patch on it. After the paint dries, the number can be written on this. Finally, coat the number with a dab of clear nail polish or shellac when the ink has dried.

With each fossil properly identified and in a tray with its label, your collection is finally ready to show off. Each collector has his own idea about how to arrange his fossil museum. Some display their fossils in an old china cabinet or bookcase. Whatnot shelves or shadow boxes can also be used to make attractive exhibits. But regardless of how you show your collection, be sure to arrange your material so that your presentation will be interesting, educational, and attractive.

As you can see, fossil collecting is a hobby that is not difficult and one that does not require a lot of expensive equipment. Now that you have been introduced to the basic "do's" and "don't's" of this interesting hobby, why not join the increasing numbers of amateur earth scientists who are happily prying ancient secrets from Earth's rocky crust?

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A member of leading professional societies in his field—he is listed in *American Men of Science* and *Who's Who in American Education*—Professor Matthews is active in educational work, particularly in matters of curriculum planning in the field of geology and earth science. He is also Visiting Geoscientist for the American Geological Institute, Washington, D. C., and Visiting Scientist for the Texas Academy of Science.

In addition to articles in a number of scientific and professional periodicals, Professor Matthews is the author of adult volumes on general geology, fossils, and prehistoric life, and laboratory manuals in geology and paleontology. A thorough knowledge of his subject matter and an ability to write about it in a lively style make his juvenile books, WONDERS OF THE DINOSAUR WORLD and WONDERS OF FOSSILS, unusually interesting ones.

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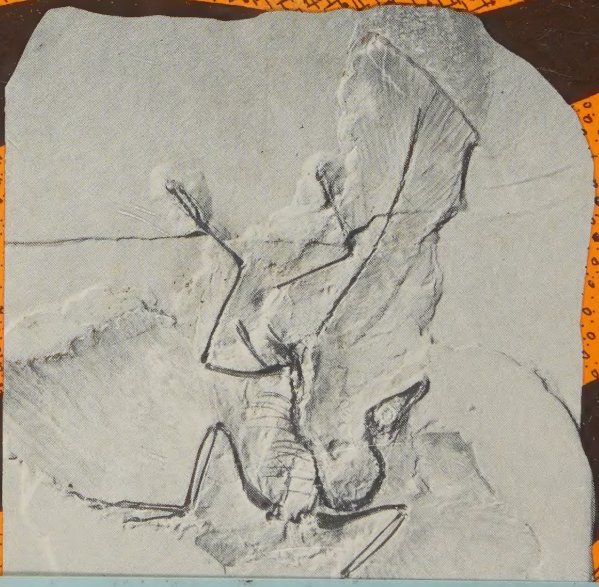

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